# Domestic Financial Frictions: Implications for International Risk Sharing, Real Exchange Rate Volatility and International Business Cycles

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**Domestic Financial Frictions:**
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Under complete international financial markets, as assumed in standard international business cycle models, a country's aggregate consumption rises relative to foreign consumption, in states of the world in which the country's real exchange rate depreciates. Empirically, relative consumption spending and the real exchange rate are essentially uncorrelated. I show that this 'consumption-real exchange rate anomaly' can be explained by a model in which only a fraction of households trade in complete financial markets, while the remaining households do not participate in financial markets, and thus act in a hand-to-mouth (HTM) manner. HTM behavior also generates a more volatile real exchange rate, which also brings the model closer to the data.

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## 1. Introduction

There is overwhelming evidence that consumption risk is imperfectly shared across countries (Obstfeld (1989, 1992)). Under full risk sharing (complete international financial markets), a country's aggregate consumption would rise relative to foreign consumption, in states of the world in which the country's real exchange rate depreciates. Yet, as documented in Table 1, relative consumptions and real exchange rates are essentially uncorrelated. That 'consumption-real exchange rate anomaly' is one of the major puzzles in international macroeconomics (Obstfeld and Rogoff (2000)). [1]

This paper investigates whether this anomaly can be explained by a very simple model in which only a fraction of households trade in complete financial markets, while the remaining households do not participate in financial markets, and thus lead a hand-to-mouth (HTM) life; each period, HTM households consume their current labor income. Empirically, a sizable fraction of households fails to participate in asset markets (Haliassos (2006)). As discussed by Mankiw (2000), HTM behavior can reflect myopia on the part of households, or simple 'rule-of-thumb' decision making. Empirically, a country's aggregate consumption growth closely tracks the growth of income (see Engel and Rogers (2008) for evidence for G7 countries). The *closed* economy literature has argued that the presence of HTM households may help to explain this fact (Campbell and Mankiw (1989)); that literature has also argued that HTM households may rationalize the macroeconomic effects of fiscal policy (e.g., Galì, Lopez-Salido and Vallès (2007); Forni, Monteforte and Sessa (2007)) and the equity premium (e.g., Weil (1990), Chien, Cole and Lustig (2007)).

In the *open* economy literature, the HTM assumption has received much less attention.[2] To capture limited international risk sharing, that literature has mostly focused on models in which only a restricted set of assets can be traded across internationally (e.g., just a risk free bond)—however, most of these models assume that each country is

[1] For empirical and theoretical discussions of this anomaly and other aspects of international risk sharing, see i.a. Obstfeld (1989), Kollmann (1991, 1995), Backus and Smith (1993), Heathcote and Perri (2002, 2004), Benigno and Thoenissen (2008), Bodenstein (2008), Corsetti, Dedola and Leduc (2008), Hoffmann (2006) and Sorensen, Wu, Yosha and Zhu (2005).

[2] Some large multi-country models allow for HTM households (e.g., Erceg et al. (2004), Ratto, Roeger and in 't Veld (2008)), but the complexity of those models makes it hard to understand the role of the HTM feature.

inhabited by a representative household.[3] Yet, in reality there is large-scale international trade in state-contingent assets (equity, derivatives); see Lane and Milesi-Ferretti (2003). Also, the data show that risk sharing is not only limited across countries, but also among the residents of the same country (e.g., Santos Monteiro (2008)).

The model here assumes complete international financial markets, but only some households have access to those markets. The remaining households lead hand-to-mouth lives. The setup here thus provides a very simple integration of *within*-country heterogeneity of households, in a model of the world economy.

In a related contribution, Kocherlakota and Pistaferri (2007) develop a model of a two-country world in which households can fully insure themselves against home and foreign aggregate productivity shocks, but not against individual-specific shocks to labor productivity. In that setup, cross-sectional heterogeneity matters for the real exchange rate. Under a private information-Pareto optimal (PIPO) insurance mechanism, a country's real exchange rate appreciates when foreign right-tail cross-sectional consumption inequality increases relative to domestic right-tail inequality. Kocherlakota and Pistaferri (2007) claim that this prediction is consistent with data on the US and UK real exchange rate and on individual US and UK household consumption. Kollmann (2009) casts doubts on the success of the PIPO model. Also, so far, the ability of the PIPO structure to match a broader set of macroeconomic stylized facts has not been studied. The PIPO model implies that the consumption of rich (high-productivity) households tracks their income more closely, than for poor households. By contrast, in the model here, wealthy households trade in complete markets.

The present model is much simpler, and it is thus more suitable for analyzing a broad set of international macroeconomic stylized facts. Devereux, Smith and Yetman (2009) also discuss the possibility that the presence of HMT households may help to explain the consumption real exchange rate anomaly.[4] However the model used by these

[3]See, e.g. Kollmann (1991,1996), Baxter and Crucini (1995), Chari, Kehoe and McGrattan (2002), Corsetti, Dedola and Leduc (2008) for multi-country bonds-only models in which each country is inhabited by a representative household. The bonds-only structure fails to explain the consumption-real exchange rate anomaly, unless the elasticity of substitution between local and imported goods is close to zero (Corsetti et al. (2008)).
[4] This paper was brought to my attention after the research here had been completed.

authors differs from that here; also, they do not discuss implications of HTM behavior for other exchange rate volatility and other macroeconomic stylized facts here.

The model here assumes a two-country world with two goods. Each country produces a single good, but uses domestic and foreign goods for consumption and physical investment; there is a local bias in consumption/investment spending. The economy is hit by shocks to output, investment spending, and to the shares of GDP received by HTM households.

In the structure here (as in standard models), output supply shocks induce a negative co-movement between a country's relative aggregate consumption, and its relative CPI (i.e. its consumption based real exchange rate): when the country's output rises, its relative consumption rises (due to a preference bias for the local good), while the relative price of the good produced by the country drops, which implies a depreciation of the country's real exchange rate.

The presence of HTM households generates two mechanisms that weaken the negative correlation between the real exchange rate and relative consumption: (i) With HTM households, relative Home consumption responds less strongly negatively to shocks that raise Home real investment--in fact a Home investment shock may increase Home relative consumption if households are sufficiently risk averse. A rise in Home country investment spending raises the relative price of the good produced by Home, which raises the relative income and consumption of Home HTM households; the relative consumption of Home non-HTM households falls—however, if risk aversion is sufficiently high, the fall of non-HTM consumption is small, and thus relative Home consumption (by HTM and non-HTM households) falls less, and may actually increase. (ii) An increase in the share of Home GDP received by Home HTM households likewise improves the Home terms of trade, and it raises Home consumption (by HTM and non-HTM households).

The responses of the real exchange rate to demand shocks (investment shocks and shocks to the share of GDP received by HTM households) are greater when there are HTM households. Intuitively, a rise in the relative price of the Home good raises the (relative) income of the HTM households. Due to consumption home bias, that income effect counteracts the negative substitution effect of the price change on the relative demand for the Home good. The positive Home income effect is stronger, the greater the share GDP received by HTM households. Hence, the (relative) demand for the Home good is less sensitive to terms of trade changes, when the income share of HTM households is high. With a high HTM income share, *larger* terms of trade (and real exchange rate) adjustments are thus needed to clear the goods market, in response to demand shocks. When the local spending bias is strong, the sensitivity of the real exchange rate to output shocks is likewise greater, the greater the income share of HTM household. The presence of HTM households raises the sensitivity of relative (Home versus Foreign) consumption to income shocks, but it dampens the effect of investment shocks.

I calibrate the model to data for the US and an aggregate of the remaining G7 countries, using the labor share (ratio of labor income to GDP) as an empirical proxy for the fraction of GDP received by HTM households. Empirically, relative (domestic vs. foreign) physical investment spending is more volatile than relative output, while the relative labor share is less volatile. Also, relative investment is highly positively correlated with relative output. With this empirical pattern of output, investment and the labor share, the model with HTM households predicts that a country's relative consumption is, essentially, uncorrelated with its real exchange rate, as is consistent with the data. The strong positive empirical correlation between output and investment is important for the ability of the model to generate a realistic consumption-real exchange rate correlation. In addition, numerical simulations show that the presence of HTM households can significantly increase the volatility of the real exchange rate, of consumption and net exports. The HTM assumption thus brings the model closer to the data, compared to standard International RBC models in which all households trade in complete financial markets (as is well known, those models underpredict the empirical volatility of the real exchange rate and of net exports, and produce cross-country consumption correlations that are too high when compared to the data).

Sections 2 present the main analytical results, based on a static model. Section 3 calibrates the static model, and reports quantitative predictions. Section 4 embeds the HTM assumption in a dynamic international RBC model. Section 5 concludes.

## 2. The model

### 2.1. Preferences, endowments and markets

I consider a world with two ex ante symmetric countries, Home (H) and Foreign (F), and two goods. Country i=H,F produces $Y_i$ units of good i. Country i is inhabited by two households: the first household is a hand-to-mouth household, HTM, whose income equals an exogenous random fraction $0 \le \lambda_i < 1$ of her country's GDP; the HTM household consumes her entire income. The second country i household receives the country's GDP, net of the income of the HTM household, and net of exogenous real 'investment' spending, $X_i$; that household trades in a complete financial market; we refer to that household as a 'risk sharer', RS. The HTM and RS households can be interpreted as a workers, and as an entrepreneur (residual claimant), respectively.

Both types of households have identical preferences. The country i household of type h=HTM,RS has utility $U(C_i^h) = \frac{1}{1-\sigma}\{(C_i^h)^{\sigma-1} - 1\}$, where $C_i^h$ is aggregate consumption:

$$C_i^h = [\alpha^{1/\phi}(c_i^{i,h})^{(\phi-1)/\phi} + (1-\alpha)^{1/\phi}(c_i^{j,h})^{(\phi-1)/\phi}]^{\phi/(\phi-1)}, \;\; j \neq i; \tag{1}$$

$c_i^{i,h}$ and $c_i^{j,h}$ are the household's consumptions of goods i and j, respectively. $\sigma>0$ and $\phi>0$ are the risk aversion coefficient, and the substitution elasticity between the two goods, respectively. There is a preference bias for the local good: $1/2<\alpha<1$. The welfare based consumer price index corresponding to these preferences is:

$$P_i \equiv [\alpha(p_i)^{1-\phi} + (1-\alpha)(p_j)^{(1-\phi)}]^{1/(1-\phi)}, \tag{2}$$

where $p_i$ is the price of good i.

The Home terms of trade and the Home (CPI-based) real exchange rate are $q \equiv p_H/p_F$ and $RER \equiv P_H/P_F$, respectively.

The real consumption of the HTM household is:

$$C_i^{HTM} = p_i \lambda_i Y_i / P_i. \tag{3}$$

Efficient risk sharing between Home and Foreign 'RS' households implies that the ratio of their marginal utilities of real consumption spending is equated to the real exchange rate (Kollmann (1991, 1995), Backus and Smith (1993)):

$$(C_H^{RS})^{-\sigma} / (C_F^{RS})^{-\sigma} = \xi \cdot RER, \tag{4}$$

where $\xi$ is a state-independent term that reflects the two countries' ex ante wealth; in the setting here, $\xi = 1$ holds, due to the ex ante symmetry of the countries.

Real investment $I_i$ is a composite good that has the same structure as aggregate consumption (1). Spending is allocated between goods H and F so that the marginal rate of substitution between these goods is equated to their relative price. Thus:

$$c_i^{i,h}=\alpha(\tfrac{p_i}{P_i})^{-\phi}C_i^H,\ c_j^{i,h}=(1-\alpha)(\tfrac{p_j}{P_i})^{-\phi}C_i^H,\ x_i^i=\alpha(\tfrac{p_i}{P_i})^{-\phi}X_i,\ x_j^i=(1-\alpha)(\tfrac{p_j}{P_i})^{-\phi}X_i\quad(j\neq i),\qquad(5)$$

where $x_j^i$ is country *i* investment demand for good *j*.

Market clearing requires:

$$c_i^{i,HTM}+c_i^{i,RS}+x_i^i+c_i^{j,HTM}+c_i^{j,RS}+x_i^j=Y_i\ \text{ for } i,j=H,F\ \text{ (with } j\neq i).\qquad(6)$$

The distributions of the exogenous variables are symmetric across countries; their expected values are: $EY_i = 1$, $\Lambda\equiv E\lambda_i\geq 0$, $\Xi\equiv EI_i>0$ with $0<\Lambda+\Xi<1$, for *i=H,F*.

The above equations pin down consumption and the real exchange rate, *given* $Y_i, I_i, \lambda_i$ for $i=H,F$. In the first part of the analysis, I will take the behavior of $Y_i, I_i, \lambda_i$ as given. I calibrate the model using data on first and second moments of $Y_i, I_i, \lambda_i$ observed for the US and an aggregate of the remaining G7 countries, and I compute the implied moments of consumption, the real exchange rate and net exports. A dynamic model is needed to endogenize investment. But note that a dynamic model will generate the same consumption-real exchange rate correlation as the static model, if the dynamic model reproduces the empirical first and second moments of relative outputs, investment and HTM income shares that are used to calibrate the static model. In the Section 4, I embed the HTM assumption in a dynamic international RBC model with endogenous output and investment spending.

### 2.2. Model solution

I compute an approximate model solution by linearizing equations (1)-(6) around mean values of the forcing variables. Endogenous variables with an upper bar refer to the point of linearization. $\hat{z}\equiv(z-\bar{z})/\bar{z}$ denotes the relative deviation of a variable $z$ from the point of linearization, $\bar{z}$. Variables without country-subscript represent ratios of Home to Foreign variables: $C^{HTM} \equiv \frac{C_H^{HTM}}{C_H^{HTM}}$, $C^{RS} \equiv \frac{C_H^{RS}}{C_H^{RS}}$, $I \equiv \frac{I_H}{I_F}$, $Y \equiv \frac{Y_H}{Y_F}$, $\lambda \equiv \frac{\lambda_H}{\lambda_F}$ etc.

Linearization of (2) implies:

$$RER = (2\alpha - 1)q; \tag{7}$$

due to local spending bias, a Home terms of trade improvement induces a real exchange rate appreciation. Linearizing (3) gives:

$$C^{HTM} = Y + \lambda + 2(1-\alpha)q. \tag{8}$$

An increase in Home GDP, an increase in the fraction of GPD received by the Home HTM household, and an improvement in Home terms of trade all raise the relative consumption of the Home HTM household (compared to the consumption of the Foreign HTM household).

From (4), the relative (Home vs. Foreign) consumption of households that engage in risk sharing (RS) is a decreasing function of Home terms of trade:

$$C^{RS} = -\tfrac{1}{\sigma}(2\alpha - 1)q. \tag{9}$$

From (5), relative world demand for goods H and F obeys: [5]

$$d \equiv \frac{c_H^{H,HTM} + c_H^{H,RS} + x_H^H + c_H^{F,HTM} + c_H^{F,RS} + x_H^F}{c_F^{H,HTM} + c_F^{H,RS} + x_F^H + c_F^{F,HTM} + c_F^{F,RS} + x_F^F} = q^{-\phi}\Omega\left(RER^{\phi} A\right), \tag{10}$$

with $\Omega(x) \equiv \frac{x + \frac{1-\alpha}{\alpha}}{1 + x\frac{1-\alpha}{\alpha}}$, $A \equiv A_H / A_F$ where $A_i \equiv C_i^{HTM} + C_i^{RS} + I_i$ is absorption in country *i*. Note that $\frac{\partial\Omega(x)}{\partial x}\Big|_{x=1} = 2\alpha - 1$. A linear approximation of (10) gives thus:

$$d = -\phi q + (2\alpha - 1)(\phi RER + A). \tag{11}$$

Using (7)-(9), relative demand for good H (*d*) can be expressed as:

$$d = -\Gamma q + (2\alpha - 1)\Lambda(\lambda + Y) + (2\alpha - 1)\Xi\hat{I}. \tag{12}$$

Here $\Gamma \equiv (1-2\alpha)^2(1-\Lambda-\Xi)/\sigma - 2(2\alpha-1)(1-\alpha)\Lambda + 4\alpha(1-\alpha)\phi$ is the price elasticity of *d.* Unless the substitution elasticity $\phi$ is very close to zero, relative demand for good H is decreasing in

[5] Similar equations for relative Home vs. Foreign demand are derived in Coeurdacier, Kollmann and Martin (2007, 2008).

the relative price of good H, $q$: $\Gamma>0$ (see Appendix).[6] The following discussions assume $\Gamma>0$.

Market clearing requires $Y=d$. (12) shows that increases in the relative share of GDP received by Home HTM households $(\lambda)$ and in relative Home real investment spending $(I)$ both raise the relative demand for good H; to ensure market clearing, those shocks thus require an improvement of the Home terms of trade (when $\Gamma>0$), and thus an appreciation of the Home real exchange rate. Intuitively, a rise in $\lambda$ or in $I$ lowers the quantity of good H consumed by (Home and Foreign) RS households; the relative consumption of Home RS households has to fall relative to that of Foreign RS households—and as a result, the relative price of good H increases (from (9)). By contrast, a rise in (relative) Home output triggers a worsening of Home terms of trade, $q$: At unchanged terms of trade, a 1% increase in $Y_H$ raises relative demand for good H by less than 1%, namely by $(2\alpha-1)\Lambda\%$; market clearing thus requires a fall in $q$. In summary:

$$RER=a_Y Y+a_I\hat{I}+a_\lambda\lambda \quad \text{with } a_Y<0, a_I>0, a_\lambda>0. \qquad (13)$$

Closed form expressions for the coefficients $a_Y, a_I, a_\lambda$ are provided in the Appendix.

Using the solution for $q$, one can use (4) and (9) to determine relative 'national' consumption $C\equiv C_H/C_F$, where $C_i\equiv C_i^{HTM}+C_i^{RS}$ $(i=H,F)$:

$$C=b_Y Y+b_I\hat{I}+b_\lambda\lambda. \qquad (14)$$

As an increase in $\lambda$ improves the Home terms of trade (provided $\Gamma>0$), it raises relative absorption in the Home country;[7] holding constant relative investment, this means that relative Home *consumption* rises: hence, $b_\lambda>0$.

Not surprisingly, an increase in relative Home output $(Y)$ raises Home relative aggregate consumption $(b_Y>0)$, for plausible parameter values (see Appendix).

[6] For very low $\phi$, the (negative) substitution effect of a rise in Home terms of trade $q$ on the demand for good H is weak, and that effect may thus be dominated by the (positive) income effect experienced by country Home HTM households; the (relative) demand for good H is then an *increasing* function of $q$.

[7] (11) and $Y=d$ imply $Y=-\phi 4\alpha(1-\alpha)q+(2\alpha-1)A$. Thus, any shock that improves the Home terms of trade, at an unchanged value of relative output, has to be associated with a rise in relative Home absorption.

An increase in relative Home investment likewise improves the Home terms of trade; this raises the relative consumption of the Home HTM household $(C^{HTM})$, but it reduces the relative consumption of the Home 'RS' households $(C^{RS})$; see (8),(9). For plausible values of $\Lambda$, the second effect dominates, i.e. $b_I<0$ (see Appendix).

Note that $\Gamma$ (the elasticity of relative demand for the two goods, with respect to the terms of trade) is decreasing in $\Lambda$ (mean GDP share received by HTM households). Intuitively, a rise in the relative price of the Home good raises the (relative) income of the HTM households. Due to consumption home bias, that income effect counteracts the negative substitution effect of the price change on the relative demand for the Home good. The positive income effect experienced by Home HTM households is stronger, the greater the share of HTM households--which explains why $\Gamma$ is decreasing in $\Lambda$.

As a result, the sensitivity of the real exchange rate to (relative) investment shocks and to shocks to the GDP received by HTM households $(\lambda)$ is higher, the greater is $\Lambda$ (see Appendix.): with a high HTM income share, larger terms of trade (and real exchange rate) adjustments are needed to clear the goods market, in response to exogenous demand shocks. Relative national consumption is less sensitive to investment shocks, but more sensitive to shocks to $\lambda$ the greater is $\Lambda$.

At constant terms of trade, an increase in Home output creates an excess supply in the market for the Home good. The greater is $\Lambda$, the smaller is that excess supply, as a greater $\Lambda$ means that Home HTM households' income rises more strongly. As the elasticity of relative demand for the two goods, with respect to the terms of trade is lower when $\Lambda$ is greater, the effect of the presence of HTM households on the sensitivity of the real exchange rate to output shocks is ambiguous. It appears that when the local spending bias is strong, the sensitivity of the real exchange rate to output shocks is higher, the greater is $\Lambda$, while the sensitivity of relative consumption is weaker (see Appendix). For values of $\alpha$ arbitrarily close to unity, the real exchange and relative consumption are approximately given by

$$RER = -\tfrac{\sigma(1-\Lambda)}{1-\Lambda-\Xi} Y + \tfrac{\sigma}{1-\Lambda-\Xi}\{\Lambda\lambda + \Xi\hat{I}\}, \quad C = \tfrac{1}{1-\Xi} Y - \tfrac{\Xi}{1-\Xi}\hat{I}\,; \qquad (15)$$

In this limiting case, the sensitivity of the real exchange rate to shocks is greater, the greater the degree of risk aversion, but it does not depend on the substitution elasticity between domestic and foreign goods, $\phi$.

In summary, output and investment shocks induce negative co-movement between the real exchange rate and relative consumption. However, the presence of HTM households dampens the negative effect of a Home investment shocks on Home relative consumption, and it strengthens the response of the real exchange rate to those shocks. Shocks to the GDP share received by HTM households are a source of positive co-movement between a country's real exchange rate and its relative national consumption. This helps to understand why, as shown below, the HTM model generates a lower and thus more realistic correlation between the real exchange rate and relative consumption, and greater real exchange rate fluctuations than a model with full risk sharing (in which there are no HTM households).

### 2.3. Two alternative asset structures

It seems interesting to compare the above model to two alternative asset market set-ups that have widely been studied in the literature: full risk sharing (e.g. Backus, Kehoe and Kydland (1994)) and financial autarky (e.g. Heathcote and Perri (2004)):

*Full risk sharing (not HTM households)*

There is full risk sharing when there are no HTM households ($\lambda_H = \lambda_F = 0$). It follows from the formulae shown in the Appendix that then $a_Y < 0, a_I > 0$ and $b_Y > 0, b_I < 0$ irrespective of the values of the preference parameters and of the mean level of investment. Thus a rise in relative output always triggers a real exchange rate depreciation, and an increase in relative consumption. A rise in relative investment appreciates the real exchange rate and lowers Home relative consumption.

*Financial autarky*

Under financial autarky, the 'RS' household cannot share risk with the rest of the world anymore, and thus her consumption equals her endowment. Therefore, total country *i* consumption equals the value of country *i* GDP, net of real investment: $C_i = p_i Y_i / P_i - I_i$.

The real exchange rate and relative consumption are given by: $RER = -\frac{2\alpha-1}{1+2\alpha(\phi-1)}Y$, $C = \frac{1}{1-\Xi}\frac{2\alpha\phi-1}{1+2\alpha(\phi-1)}Y - \frac{\Xi}{1-\Xi}\hat{I}$. Unless the substitution elasticity $\phi$ is close to zero, a Home relative output shock depreciates the real exchange rate and it raises Home relative consumption.[8] Note that, under financial autarky, a rise in investment always crowds out private consumption, and that it has no effect on the real exchange rate; shocks to $\lambda$ have no effect on relative consumption or the real exchange rate.

*Comparison between the three asset market structures*

All three asset markets setups predict that the Home real exchange rate and relative Home consumption move in opposite directions, in response to output shocks (unless $\phi$ is very low). In all three setups, investment shocks likewise induce the real exchange rate and relative consumption to move in opposite directions; but, as discussed above, the presence of HTM households strengthens the response of the real exchange rate, and dampens the response of relative consumption to investment shocks. Finally, the HTM model includes a shock that induced positive co-movement between the real exchange rate and relative consumption: shocks to the fraction of output received by HTM households $(\lambda_i)$.

## 2.4. Model calibration

Building on Kollmann (1998 and 2004), I calibrate the model to data for the US and an aggregate of the remaining G7 countries (Japan, Germany, France, UK, Italy and Canada), henceforth referred to as the 'G6'.

*Preference parameters, investment and HTM income shares*

US exports [imports] to/from the G6 amounted to 3.10% [4.64%] of US GDP and 2.44% [3.71%] of G6 GDP, on average during the period 1980-2003. Thus the average US-G6 trade share was about 3.5%. [9] Accordingly, I set $\alpha = 0.965$, in the model.

[8] The real exchange depreciates if $\phi > \frac{2\alpha-1}{2\alpha}$ (e.g., if $\alpha = 0.8$ there is a depreciation when $\phi > 0.375$).

[9] Data source: IMF Directions of Trade Statistics database. Unless indicated otherwise, all other data used in this paper are taken from IMF International Financial Statistics.

The substitution elasticity $\phi$ corresponds to the price elasticity of a country's (aggregate) import and export demand functions. Hooper and Marquez (1995) survey a large number of time-series studies that estimated price elasticities of aggregate trade flows, for the US, Japan, Germany, the UK and Canada; the median estimates (post-Bretton Woods era) of $\phi$ for those countries are 0.97, 0.80, 0.57, 0.6, and 1.01, respectively; the median estimate across all 5 countries is 0.9. Accordingly, I set $\phi = 0.9$. Estimates of the risk aversion coefficient $\sigma$ in the range of 2 or greater are common for industrialized countries (e.g., Barrionuevo (1992)). I set $\sigma = 2$.

Across G7 countries, the mean investment spending/GDP ratio (1972-2003) is 22%. I hence set $\Xi$=0.22.

I consider a benchmark case in which, on average, 50% of total consumption accrues to HTM households, as suggested by Campbell and Mankiw's empirical study (1989)). Ss investment spending is 22% of GDP on average, this implies that HTM consumption represents 39% (=0.5*(1-0.22)) of GDP, on average: $\Lambda$=0.39.

*Stochastic properties of the forcing variables*

Empirically, participation in financial markets is highly positively correlated with household wealth; households whose main source of income is labor income are less likely to hold internationally traded assets (e.g. Haliassos (2006)). I thus take fluctuations in the labor share (fraction of GDP received by labor) as a proxy for movements in the fraction of GDP received by HTM households, $\lambda_i$.

US and G6 output, investment and labor shares undergo highly persistent fluctuations. I calibrate the second moment of the forcing variables to second moments of *growth rates* of US and G6 annual GPD, real investment and labor shares for 1973-2003 (all empirical time series used in this paper are annual).[10]

The standard deviations of annual growth rates of relative US/G6 real GDP is 1.70%; the standard deviations of the growth rates of relative real physical investment

[10] G6 variables are geometric weighted averages of individual G6 countries' variables (weights: time averaged shares in aggregate G6 GDP). In the theoretical model, $X_i$ represents country *i* real investment spending, in units of final consumption; hence, my empirical measure of $X_i$ is nominal investment deflated by the CPI. The empirical measure of the wage share is (compensation of employees)/(GDP-indirect taxes), from OECD National Accounts.

and of the relative labor shares are 7.69% and 1.41%, respectively. The correlation between growth rates of relative US/G6 output and relative investment is 0.86; relative labor share growth is slightly positively correlated with relative output growth (0.09) and negatively correlated with relative investment growth (-0.16). The growth rates of US and G6 relative investment are markedly volatile than relative output growth, while the growth rate of the relative labor share is slightly less volatile. Relative output and relative investment (growth) are highly positively correlated. Based on this evidence, I set:

$$std(Y)=1.70\%, std(\hat{I})=7.69\%, std(\lambda)=1.41\%,$$

$$Corr(Y,\hat{I})=0.86, Corr(Y,\lambda)=0.09, Corr(\hat{I},\lambda)=-0.16\,. \qquad (16a)$$

These six moments pin down the standard deviations and cross-correlations of the real exchange rate and relative consumption, in the model. In addition, the predictions of the model for the moments of consumption in an individual country are of interest. To obtain those predictions, the second moments of the levels of the forcing variables have to be specified. To ensure symmetry of distributions across countries, I set the standard deviations and *within-country* correlations of forcing variables at averages (across the US and G6) of the corresponding empirical moments. This gives:

$$std(Y_i)=1.76\%, std(I_i)=6.84\%, std(\lambda_i)=1.04\%\,,$$

$$Corr(Y_i,I_i)=0.90, Corr(Y_i,\lambda_i)=-0.26, Corr(I_i,\lambda_i)=-0.36 \text{ for i=H,F.} \qquad (16b)$$

Thus, investment in a given country is more volatile than output or the labor share. Investment is strongly procyclical, while the labor share is countercyclical. The moments in (16a)-(16b) pin down the *cross-country* correlations of the forcing variables.[11] The implied cross-country correlations are: $Corr(Y_H,Y_F)=0.53$, $Corr(I_H,I_F)=0.36$, $Corr(\lambda_H,\lambda_F)=0.09$, $Corr(Y_i,I_j)=0.42$, $Corr(Y_i,\lambda_j)=-0.34$, $Corr(I_i,\lambda_j)=-0.24$ for $i\neq j$.

[11] E.g. the cross-country output correlation can be computed using $Corr(Y_H,Y_F)=1-0.5Var(Y_H-Y_F)/Var(Y_H)$. As the shock processes is calibrated so that it matches the empirical second moments of relative (US vs. G6) forcing variables exactly (see (16a)), and so that it reproduces the *average* values (across the US and G6) of empirical within-country second moments (see (16b)), the implied theoretical cross-country correlations differ from the empirical correlations (this is the price one has to pay, in order to keep cross-country symmetry of the distribution of forcing variables). However, the implied cross-country correlations are close to the empirical correlations. For example, the implied cross-country correlations of output and of investment are 0.53 and 0.36, respectively (as reported in the text); the corresponding empirical correlations (between the US and G6) are 0.56 and 0.40, respectively.

Thus, output is highly positively correlated across countries. Output in a given country is positively correlated with foreign investment and negatively correlated with the foreign labor share.

## 3. Stylized facts and model predictions

### 3.1. Stylized facts

Table 1 (Column 1) reports empirical correlations between relative US/G6 (annual) consumption and the relative US/G6 real exchange rate. The correlations are reported both for non-durables plus services purchases, and for total consumption (that includes spending on durables). The correlations pertain to logged times series that were detrended by first differencing, HP filtering and linearly detrending. The US/G6 consumption-real exchange rate correlations for non-durables are close to zero, and statistically insignificant. By contrast, relative *total* US/G6 consumption is positively correlated with the relative price of US consumption.

Table 1 also shows consumption-real exchange rate correlations for each other G7 country (relative to an aggregate of the remaining G7 countries). The correlations are generally close to zero and statistically insignificant.

Table 3 (column labeled ‘Data’) reports other empirical macro statistics (averages of US and G7 statistics based on growth rates of annual time series, 1972-2003).

Empirically, consumption and net exports (normalized by GDP) are less volatile than output, while the real exchange rate is markedly more volatile than GDP. The standard deviations of output, consumption, net exports and the real exchange rate are 1.76%, 1.19%, 0.29% and 7.70%, respectively (the empirical consumption measure used here is non-durables plus services spending; empirical net exports are net exports between the US and G6, normalized by GDP). Empirically, consumption is procyclical, while net exports and the real exchange rate are slightly countercyclical. The US-G6 cross-country correlations of consumption (0.42) and investment (0.36) are somewhat smaller than the correlation between US and G6 GDP (0.53).

### 3.2. Model predictions

Table 2 reports the coefficients of the solutions for the real exchange rate and relative (Home vs. Foreign) consumption, for the HTM model, and for the model with full risk sharing (no HTM households). In the benchmark HTM model, the equilibrium real exchange rate and relative consumption are (see Panel (a), Table 2):

$$RER = -2.23Y + 0.71\hat{I} + 1.24\lambda, \quad C = 0.97Y - 0.15\hat{I} + 0.23\lambda.$$

Thus, a 1% relative Home output increase depreciates the Home real exchange rate by 2.23%, and it raises Home relative consumption by 0.97%. A 1% shock to relative Home investment appreciates the Home real exchange rate by 0.71% and reduces relative Home consumption by 0.15%. A 1% shock to the share of the Home GDP received by HTM households appreciates the Home real exchange rate by 1.27% and raises Home relative consumption by 0.23%.

With full risk sharing (no HTM households), the real exchange rate and relative consumption obey:

$$RER = -2.02Y + 0.41X, \quad C = 1.01Y - 0.20X.$$

Thus, the response of the real exchange rate to investment shocks is 73% stronger, while the response of relative consumption is 75% weaker in the benchmark HTM structure (compared to the model with full risk sharing).

Table 3 reports the predicted consumption-real exchange rate correlation and other moments generated by the model. Columns (1)-(3) pertain to the benchmark HTM structure (Col. (1) assumes $Y, I, \lambda$ shocks, while Cols. (2) and (3) assume just $Y$ and $I$ shocks, and just $Y$ and $\lambda$ shocks, respectively). Col. (4) assumes full risk sharing, while Col. (5) assumes financial autarky.

The benchmark HTM model with ($Y, I$ and $\lambda$ shocks) predicts $corr(C, RER) = -0.07$ (see Panel (a) of Table 3). Thus, the predicted correlation is close to zero--and hence close to the empirical correlation (0.03). The 'full-risk-sharing' structure predicts that $corr(C, RER) = -1$, while $corr(C, RER) = -0.10$ under financial autarky.

The presence of all three (relative) shocks is key for explaining the low C-RER correlation generated by the benchmark HTM model; when there are just output and investment shocks (no $\lambda$ shock), the predicted consumption-RER correlation is -0.39 in the HTM model; with just Y and $\lambda$ shocks, the correlation is -0.79.

The strong positive correlation between Y and I (0.90) assumed in the model is a key ingredient that enables that model to generate a realistic C-RER correlation. Shocks to Y and I drive C and RER in opposite directions. However, in the benchmark calibration, a positive Y shock tends to be associated with a positive I shock—which dampens the volatility of the real exchange rate and of consumption, and makes the C-RER correlation less negative. The role of the positive Y-I correlation is highlighted in Panel (b) of Table 3, where I set the Y-I correlation to zero; in that case, the C-RER correlation in the HTM structure is noticeably smaller than in the benchmark model: -0.86 (with simultaneous $Y, I, \lambda$ shocks). (In the benchmark model, $\lambda$ is correlated with Y and I. But as those correlations are small, they have a minor effect on the predicted C-RER correlation. Setting the correlation of $\lambda$ with Y and I to zero lowers the C-RER correlation slightly to -0.13; not shown in Table.)

The predicted standard deviation of the real exchange rate is 2.69% in the benchmark HTM structure, compared to 1.74% under full risk sharing and 1.96% under financial autarky. In the HTM structure, the predicted standard deviations of consumption (0.96%) and net exports (0.13%), and the correlation between consumption and output (0.63) are likewise higher, and closer to the corresponding empirical moments (1.19%, 0.29% and 0.57); the predicted correlation between Home and Foreign correlation is 0.40, which is very close to the empirical correlation, 0.42 (the full risk sharing generates a cross-country consumption correlation of 0.54). The HTM and full risk sharing models both capture the fact that net exports are countercyclical.

*A model variant with a larger expected income share of HTM households* $(\Lambda = 0.6)$

The predicted C-RER correlation is increasing in the mean income share of HTM households, $\Lambda$. In Panel (c) of Table 3, I set $\Lambda$ at a larger value than in the benchmark calibration, namely at the labor share observed in G7 countries: $\Lambda$=0.6 (compared to $\Lambda$=0.39 in the benchmark case); in other terms it is assumed there that all workers are hand-to-mouth consumers. When $\Lambda$=0.6, the predicted standard deviation of the real exchange rate (6.91%) almost matches the empirical volatility (7.7%), but the consumption-real exchange rate correlation now is too large (0.62), while the predicted cross-country consumption correlation (0.04) is too low (with simultaneous $Y,I,\lambda$ shocks). In the variant with $\Lambda$=0.6 the real exchange rate is much more sensitive to shocks to $I$ and $\lambda$ than under the benchmark calibration, while relative consumption is less sensitive to shocks to $I$ and more sensitive to $\lambda-$shocks ($a_I$=1.18, $a_\lambda$=3.23, $b_I$=$-$0.06, $a_\lambda$=0.58; see Panel (c) in Table 2).

*Model variant with a lower expected income share of HTM households* ($\Lambda = 0.25$)

Panel (d) in Table 3 reports results for a model variant with $\Lambda$=0.25. The predicted C-RER correlation generated by the HTM structure now is $-0.61$, while the standard deviation of the real exchange rate is 1.92%. Thus, even a relatively small HTM income share of 25% generates a C-RER correlation that is markedly closer to the empirical correlation than the model with full risk sharing (where the C-RER correlation is -1).

*Model variant with greater risk aversion* ($\sigma$=5)

With greater risk aversion, $\sigma$=5 (compared to $\sigma$=2 in the benchmark calibration), the relative consumption of Home vs. Foreign non-HTM households responds less to a given change in the terms of trade, $q$ (see (4)); this implies that relative worldwide demand for the Home good is less sensitive to the terms of trade. As a result, the real exchange rate becomes more sensitive to the three (relative) shocks. Greater risk aversion dampens the response of relative consumption to output and investment shocks, but strengthens the response to $\lambda-$shocks (see Table 2 and Appendix). Panel (e) reports results for a model variant in which the risk aversion coefficient is set at $\sigma$=5 (compared to $\sigma$=2 in the benchmark calibration). In the HTM structure, the real exchange rate is now positively correlated with relative Home vs. Foreign consumption (correlation: 0.20), and the standard deviation of the real exchange rate is 4.35%--i.e. the real exchange rate is now about 2.4 times as volatile as output. The other predicted moments reported in the Table are also roughly in line with the empirical moments.

Note that the structure with full risk sharing also generates a greater standard deviation of the real exchange rate (3.12%) when the risk aversion coefficient is set at $\sigma$=5; but note the real exchange rate remains less volatile than in the HTM structure, and that the cross-country consumption correlation under full risk sharing (0.73) is larger than the empirical correlation (0.42).

*Model variants with a higher substitution elasticity between domestic and foreign goods* $(\phi=2)$ *and with a higher trade share* $(\alpha=0.8)\backslash$

Panels (f) of Table 3 reports results for a model variant in which domestic and foreign goods are more substitutable than in the benchmark calibration $(\phi=2)$, while Panel (g) assumes a 20% mean trade share (mean trade share in benchmark case: 3.5%); this 'high-trade' variant may shed light on the effect of shocks within Europe.

The real exchange rate and relative consumption respond less strongly to shocks when the substitution elasticity and the trade shares are higher than in the benchmark calibration. The predicted volatility of the real exchange rate falls thus (to 1.72% in variant with $\phi=2$ and 0.65% in the 'high-trade' model variant). Empirically, more open economies have less volatile real exchange rates (e.g., Kollmann (2004)). However, the correlation between the real exchange rate and relative consumption induced by the HTM-structure remains much larger than under full risk sharing: 0.12 when $\phi=2$, and $-0.41$ when $\alpha=0.8$.

## 4. A dynamic model with endogenous production and investment

This Section discusses a model variant with endogenous production and physical investment. I assume that country *i* output is generated using the production function $Y_{i,t}=\theta_{i,t}(K_{i,t})^{\kappa}$, $0<\kappa<1$, where $K_{i,t}$ is the country's physical capital stock in period t, while $\theta_{i,t}>0$ is an exogenous technology parameter (TFP). The law of motion of the capital stock is: $K_{i,t+1}=K_{i,t}(1-\delta)+\chi_{i,t}I_{i,t}$, where $0<\delta<1$ is the depreciation rate of capital. $I_{i,t}$ is gross investment in period t. $\chi_{i,t}>0$ is an exogenous shock to the efficiency of physical investment (see Fischer (2002, 2006), Greenwood, Hercowitz and Krusell

(1997), Justiniano, Primiceri and Tambalotti (2007)).[12] The stochastic properties of the exogenous shocks $\theta_{i,t}, \chi_{i,t}$ are symmetric across countries.

In both countries, gross investment is generated using Home and Foreign inputs, using an aggregator that has the same form as the consumption aggregator (1). Optimal physical investment in country i obeys the following Euler equation:

$$1 = E_t\beta(C_{i,t+1}/C_{i,t})^{-\sigma}(\chi_{i,t}/P_{i,t+1})[p_{i,t+1}\theta_{i,t+1}\kappa(K_{i,t+1})^{\kappa-1}+(1-\delta)P_{i,t+1}/\chi_{i,t+1}].$$

As is standard in annual macro models, I set the depreciation rate of capital and the subjective discount factor at $\delta$=0.1 and $\beta$=0.96, respectively. All other preference parameters are set at the same values as in the static model discussed above. The parameter of the production function, $\kappa$, is set at $\kappa$=0.40.

As in the static model above, an exogenous share $\lambda_i$ of country *i* GDP is received by the country's HTM household. All exogenous variables follow AR(1) processes:

$$\log(\theta_{i,t+1})=\rho^{\theta}\log(\theta_{i,t})+\varepsilon^{\theta}_{i,t},$$

$$\log(\chi_{i,t+1})=\rho^{\chi}\log(\chi_{i,t})+\varepsilon^{\chi}_{i,t},$$

$$\log(\lambda_{i,t+1}/\Lambda)=\rho^{\lambda}\log(\lambda_{i,t}/\Lambda)+\varepsilon^{\lambda}_{i,t}.$$

Following Coeurdacier, Kollmann and Martin (2008), I take the ratio of a country's CPI to its investment expenditure deflator as an estimate of the efficiency of physical investment, $\chi_{i,t}$. I fit AR(1) processes to US and G6 times series on TFP, and labor shares and this measure of investment efficiency (a linear time trend is included in the AR regression for TFP and investment efficiency). Based on annual time data, these authors report that the mean (across G7 countries) autocorrelation of these variables are 0.75, 0.79 and 0.72, respectively, and that mean standard deviations of innovations to the three forcing variables are 1.20%, 1.73% and 1.40%, respectively. Accordingly, the simulations assume $\rho^{\theta}$=0.75, $\rho^{\chi}$=0.79 and $\rho^{\lambda}$=0.72; $Std(\varepsilon^{\theta}_{i,t})$=1.20%, $Std(\varepsilon^{\chi}_{i,t})$=1.73%, $Std(\varepsilon^{\lambda}_{i,t})$=1.40%. Empirically, the cross country correlation of each type of innovation is positive; TFP innovations are weakly positively correlated with innovations to investment efficiency, while labor share innovations are negatively

[12] The model here builds on Coeurdacier, Kollmann and Martin's (2008) two –country RBC model with shocks to TFP and investment efficiency. A closely related model is also studied by Raffo (2008).

correlated with TFP and investment efficiency innovations. The simulations allow for correlation between the innovations to the Home and Foreign forcing variables.[13] As in the static model, I assume that 50% of consumption is accounted for by HTM households, in steady state.

Table 4 shows simulation results for the dynamic model. The dynamic model matches the low consumption-real exchange rate correlations seen in the data, but it generates a real exchange rate that is not sufficiently volatile, essentially, because the IRBC model generates investment series that are insufficiently volatile.

## 5. Conclusion

This paper has shown that a model with hand-to-mouth (HTM) households can contribute to solving one of the main puzzles in international macroeconomics—the fact that real exchange rates and relative consumptions are essentially uncorrelated. The model can also generate markedly more volatile real exchange rates, especially when trade shares are low and households are highly risk averse.

[13] Based on G7 data, the following (symmetrized) correlations are assumed: $Corr(\varepsilon^{\theta}_{i,t},\varepsilon^{\chi}_{i,t})=0.04$, $Corr(\varepsilon^{\theta}_{i,t},\varepsilon^{\lambda}_{i,t})=-0.49$, $Corr(\varepsilon^{\chi}_{i,t},\varepsilon^{\lambda}_{i,t})=-0.17$, for $i=H,F;$ $Corr(\varepsilon^{\theta}_{i,t},\varepsilon^{\theta}_{j,t})=0.43$, $Corr(\varepsilon^{\chi}_{i,t},\varepsilon^{\chi}_{j,t})=0.19$, $Corr(\varepsilon^{\lambda}_{i,t},\varepsilon^{\lambda}_{j,t})=0.32$, $Corr(\varepsilon^{\theta}_{i,t},\varepsilon^{\chi}_{j,t})=0.09$, $Corr(\varepsilon^{\theta}_{i,t},\varepsilon^{\lambda}_{j,t})=-0.27$, $Corr(\varepsilon^{\chi}_{i,t},\varepsilon^{\lambda}_{j,t})=-0.14$ for $i\neq j$.

**APPENDIX**
**Closed form solution for the equilibrium real exchange rate and relative national consumption (HTM model)**

(12) and the market clearing condition $Y=d$ imply

$$RER = a_Y Y + a_I \hat{I} + a_\lambda \lambda \text{, with}$$
$$a_Y \equiv [\Lambda(2\alpha-1)^2+(1-2\alpha)]/\Gamma, \quad a_I \equiv \Xi(2\alpha-1)^2/\Gamma, \quad a_\lambda \equiv \Lambda(2\alpha-1)^2/(\sigma\Gamma).$$

Country $i$ total consumption is $C_i \equiv C_i^{HTM}+C_i^{RS}$. Thus, relative consumption $C \equiv C_H/C_F$ obeys: $C = \frac{\Lambda}{1-\Lambda-\Xi}C^{HTM} + \frac{1-\Xi}{1-\Lambda-\Xi}C^{RS}$. (8), (9) and the solution for $q=RER/(2\alpha-1)$ give

$$C = b_Y Y + b_I \hat{I} + b_\lambda \lambda \text{,with}$$
$$b_Y \equiv \tfrac{1}{1-\Xi}\tfrac{1}{\sigma}[(1-\Lambda-\Xi)(2\alpha-1)-\sigma\Lambda 2(1-\alpha)(1-2\phi\alpha)]/\Gamma,$$
$$b_I \equiv \tfrac{\Xi}{1-\Xi}\tfrac{1}{\sigma}[-(1-\Lambda-\Xi)(2\alpha-1)^2+\sigma\Lambda 2(2\alpha-1)(1-\alpha)]/\Gamma,$$
$$b_\lambda \equiv \tfrac{\Lambda}{1-\Xi}4\alpha(1-\alpha)\phi/\Gamma .$$

Recall that $\Gamma \equiv (1-2\alpha)^2(1-\Lambda-\Xi)/\sigma - 2(2\alpha-1)(1-\alpha)\Lambda + 4\alpha(1-\alpha)\phi$ is the price elasticity of relative world demand for the Home-produced good (see (12)). Note that $\Gamma>0$ holds iff $\phi > \Lambda\frac{2\alpha-1}{2\alpha} - \frac{(1-2\alpha)^2(1-\Lambda-\Xi)}{4\alpha(1-\alpha)\sigma}$. The right-hand side of this inequality cannot exceed 0.5 (as $\alpha<1$ and $\Lambda \le 1$); in fact, for reasonable parameter values, the right-hand side is much below 0.5. Consider the values for $\alpha, \Xi, \Lambda$ used in the model calibration: $\alpha=0.965$, $\Xi=0.22$, $\Lambda=0.39$. For these values, $\Gamma>0$ holds whenever $\phi > 0.188-2.497/\sigma$. As discussed in the text, estimates of $\phi$ based on the response of aggregate trade flows to terms of trade changes are generally in the range of unity; estimates of $\phi$ based on sectorally disaggregated trade data are mostly greater than 4 (see Kollmann (2006)). Hence, $\Gamma>0$ is plausible. $\Gamma>0$ implies that $a_Y<0$, $a_I>0$, $a_\lambda>0$: an increase in Home (relative) output depreciates the Home real exchange rate; while increases in Home investment and in the share of Home GDP that accrues to Home HTM households appreciate the real exchange rate.

An increase in relative output raises relative consumption ($b_Y>0$), for plausible parameter values: when $\Gamma>0$ holds, then $b_Y>0$ obtains when $\phi > \frac{1}{2\alpha} - \frac{1-\Lambda-\Xi}{\Lambda}\frac{1}{\sigma}\frac{2\alpha-1}{4\alpha(1-\alpha)}$. Again, assume $\alpha=0.965$, $\Xi=0.22$, $\Lambda=0.39$; then $b_Y>0$ when $\phi>0.518-6.88/\sigma$. Assume (as in the baseline calibration) that $\sigma=2$; then $b_Y>0$ holds for any admissible (positive) value of $\phi$. An increase in relative investment lowers relative consumption ($b_I<0$) when $\Gamma>0$ *and* $\sigma < \frac{1-\Lambda-\Xi}{\Lambda}\frac{2\alpha-1}{2(1-\alpha)}$ hold; for the values of $\alpha, \Lambda, \Xi$ used in the calibration, $b_I<0$ obtain when $\sigma<13.285$.

*Effect of changes in $\Lambda$ on the sensitivity of the real exchange rate and relative consumption to shocks*

The effect of an increase in $\Lambda$ (the average share of GDP received by the HTM households) on the sensitivity of the real exchange rate and of relative consumption to output shocks is ambiguous. Because $a_Y < 0$ and $b_Y > 0$ (under plausible assumptions; see above), an increase in $\Lambda$ makes the real exchange rate and relative consumption more sensitive to output shocks when $\partial a_Y/\partial\Lambda < 0$ and $\partial b_Y/\partial\Lambda < 0$. These inequalities hold iff $\sigma < [(2\alpha-1)^2\Xi + 2(2\alpha-1)(1-\alpha)]/[2(1-\alpha)(2\alpha\phi-1)]$. This condition is always met under log preferences, $\sigma = \phi = 1$; it also holds when the local spending bias parameter $\alpha$ is sufficiently close to unity (the right-hand side of the above inequality tends to infinity when $\alpha$ tends to 1).

Note that $\partial\Gamma/\partial\Lambda = -(1-2\alpha)^2 - 2(2\alpha-1)(1-\alpha) < 0$. When $\Gamma > 0$ holds, an increase in $\Lambda$ raises thus the absolute value of the coefficients $a_I$ and $a_\lambda$. Hence the sensitivity of the real exchange rate to shocks to investment and to the income share of HTM households is greater, the higher $\Lambda$.

By contrast, the effect of an increase in $\Lambda$ on the sensitivity of relative consumption to shocks to investment and to the income share of HTM households is ambiguous. $\partial b_I/\partial\Lambda > 0$ and $\partial b_\lambda/\partial\Lambda > 0$ hold iff $\Lambda < (2\alpha-1)(1-\Xi)/[2(1-\alpha)\sigma + 2\alpha - 1]$. Thus, as long as this inequality holds, an increase in $\Lambda$ makes relative consumption less sensitive to investment shocks. Take an economy with full risk sharing, i.e. where $\Lambda = 0$; in that economy, a small increase in $\Lambda$ will raise $b_I$ and thus make relative consumption *less* sensitive to investment shocks. When $\alpha$ is close to unity, i.e. when the trade share is low, then the right-hand side of the above inequality is close to $1-\Xi$, and thus $\partial b_I/\partial\Lambda > 0$ holds, unless $\Lambda$ is very close to its upper bound $1-\Xi$. For the values of $\alpha, \sigma, \Xi$ used in the benchmark calibration, $\partial b_\lambda/\partial\Lambda > 0$ holds when $\Lambda < 0.68$.

*Effect of changes in risk aversion $\sigma$ on responses of the real exchange rate and relative consumption to shocks*

An increase in the risk aversion coefficient $\sigma$ lowers the elasticity of the relative demand for Home/Foreign goods with respect to the Home terms of trade: $\partial\Gamma/\partial\sigma = -(2\alpha-1)^2(1-\Lambda-\Xi)/\sigma^2 < 0$. This explains why an increase in $\sigma$ makes the real exchange are more sensitive to the three shocks:

$\partial a_Y/\partial\sigma = (2\alpha-1)^3[(2\alpha-1)\Lambda-1](1-\Lambda-\Xi)/\Gamma^2 < 0$ (NB $(2\alpha-1)\Lambda-1 < 0$);

$\partial a_I/\partial\sigma = \partial a_\lambda/\partial\sigma = (2\alpha-1)^4(1-\Lambda-\Xi)/\Gamma^2 > 0$.

(Note that $a_Y < 0$, so that $\partial a_Y/\partial\sigma < 0$ means that the real exchange rate responds *more* strongly to output shocks when $\sigma$ is greater.)

An increase in risk aversion dampens the effect of output and investment shocks on relative consumption, and strengthens the effect of shocks to $\lambda$:

$\partial b_Y/\sigma = (1-\Xi)^{-1}4\alpha(1-\alpha)\phi(2\alpha-1)((2\alpha-1)\Lambda-1)(1-\Lambda-\Xi)/\Gamma^2 < 0;$

$\partial b_I/\partial\sigma = \partial b_\lambda/\partial\sigma = (1-\Xi)^{-1}4\alpha(1-\alpha)\phi(2\alpha-1)^2(1-\Lambda-\Xi)/\Gamma^2 > 0.$

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**Table 1. Empirical correlation between relative consumption and real exchange rate**

| | US | Japan | Germany | France | UK | Italy | Canada | mean |
|---|---|---|---|---|---|---|---|---|
| | *(1)* | *(2)* | *(3)* | *(4)* | *(5)* | *(6)* | *(7)* | *(8)* |
| *(a) Non-durables and services consumption* | | | | | | | | |
| **First differenced** | 0.03 | -0.29 | -- | -0.10 | 0.29 | -0.11 | -0.00 | -0.03 |
| | *(0.77)* | *(0.14)* | | *(0.69)* | *(0.00)* | *(0.31)* | *(0.98)* | |
| **HP-filtered** | -0.01 | -0.29 | -- | -0.21 | 0.05 | -0.21 | -0.30 | -0.16 |
| | *(0.94)* | *(0.23)* | | *(0.24)* | *(0.70)* | *(0.06)* | *(0.30)* | |
| **Linearly detrended** | 0.09 | -0.15 | -- | -0.17 | -0.14 | -0.24 | -0.35 | -0.16 |
| | *(0.62)* | *(0.54)* | | *(0.31)* | *(0.34)* | *(0.05)* | *(0.15)* | |
| *(b) Total consumption* | | | | | | | | |
| **First differenced** | 0.13 | -0.12 | -0.06 | 0.09 | 0.05 | 0.10 | 0.01 | 0.03 |
| | *(0.16)* | *(0.34)* | *(0.37)* | *(0.34)* | *(0.75)* | *(0.53)* | *(0.90)* | |
| **HP-filtered** | 0.34 | 0.06 | 0.31 | -0.08 | 0.08 | 0.16 | -0.02 | 0.12 |
| | *(0.00)* | *(0.73)* | *(0.00)* | *(0.51)* | *(0.47)* | *(0.22)* | *(0.88)* | |
| **Linearly detrended** | 0.51 | 0.56 | 0.45 | -0.20 | 0.03 | 0.03 | -0.03 | 0.16 |
| | *(0.00)* | *(0.00)* | *(0.00)* | *(0.22)* | *(0.82)* | *(0.82)* | *(0.83)* | |

Note: Columns (1)-(7) shows correlations between the detrended log of relative consumption in a given country (compared to a GDP weighted geometric mean of consumption in an aggregate of the remaining G7 countries) and the detrended log of that country's real exchange rate (the country's consumption price index, divided by a GDP weighted average of the price indices of the remaining G7 countries, expressed in a common currency). Column (8) shows mean correlations (across the G7 countries). All data are annual. Panel (a) is based on the 1971-1987 price and quantity data on non-durables and services consumption (from OECD National Accounts) used by Kollmann (1995)). Panel (b) is based on total consumption data (including durables), for 1972-2003. Results are show for three detrending methods: first differencing, HP-filtering and linear detrending. Figures in parentheses: p-values of two-sided test of the hypothesis that correlations are zero (from GMM-based standard errors or correlation, assuming fourth order serial correlation of residuals).

**Table 2. Static model: solutions for real exchange rate and relative consumption**

| | HTM model | | | | | | Full risk sharing | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | $a_Y$ | $a_I$ | $a_\lambda$ | $b_Y$ | $b_I$ | $b_\lambda$ | $a_Y$ | $a_I$ | $b_Y$ | $b_I$ |
| **(a) Baseline calibration** | | | | | | | | | | |
| | -2.23 | 0.71 | 1.24 | 0.97 | -0.15 | 0.23 | -2.02 | 0.41 | 1.01 | -0.20 |
| **(b) Zero correlation between investment and output** | | | | | | | | | | |
| | -2.23 | 0.71 | 1.24 | 0.97 | -0.15 | 0.23 | -2.02 | 0.41 | 1.01 | -0.20 |
| **(c) High HTM income share,** $\Lambda = 0.6$ | | | | | | | | | | |
| | -2.56 | 1.18 | 3.23 | 0.91 | -0.06 | 0.58 | -2.02 | 0.41 | 1.01 | -0.20 |
| **(d) Low HTM income share,** $\Lambda = 0.25$ | | | | | | | | | | |
| | -2.13 | 0.56 | 0.64 | 0.99 | -0.18 | 0.11 | -2.02 | 0.41 | 1.01 | -0.20 |
| **(e) High risk aversion,** $\sigma = 5$ | | | | | | | | | | |
| | -3.62 | 1.16 | 2.06 | 0.72 | -0.07 | 0.37 | -3.62 | 0.74 | 0.72 | -0.14 |
| **(f) High substitution elasticity between domestic and foreign goods,** $\phi = 2$ | | | | | | | | | | |
| | -1.43 | 0.46 | 0.81 | 0.80 | -0.09 | 0.32 | -1.53 | 0.31 | 0.76 | -0.15 |
| **(g) High trade share,** $\alpha = 0.8$ | | | | | | | | | | |
| | -0.83 | 0.14 | 0.25 | 0.43 | 0.01 | 0.52 | -0.83 | 0.11 | 0.41 | -0.05 |

Note: The Table reports the coefficients of the (log-)linearized model solution that express the real exchange rate $RER \equiv P_H/P_F$ and relative (Home versus Foreign) consumption $C \equiv C_H/C_F$ as functions of relative output $Y \equiv Y_H/Y_F$, relative investment $I \equiv I_H/I_F$ and the relative shares of Home and Foreign GDP received by hand-to-mouth (HTM) households $\lambda \equiv \lambda_H/\lambda_F$: $RER = a_Y Y + a_I \hat{I} + a_\lambda \lambda$, $C = b_Y Y + b_I \hat{I} + b_\lambda \lambda$

**Table 3. The static model: predicted moments**

| | HTM model Shocks to: | | | Full risk sharing Shocks to: | Financial autarky Shocks to: | |
|---|---|---|---|---|---|---|
| | ***Y,I,λ*** | ***Y,I*** | ***Y,λ*** | ***Y,I*** | ***Y,I*** | **Data** |
| | *(1)* | *(2)* | *(3)* | *(4)* | *(5)* | *(6)* |
| **Calibrated moments:** | | | | | | |
| $Std(Y_i)$=1.76%, $Std(I_i)$=6.84%, $Corr(I_i,Y_i)$=0.90, $Corr(Y_H,Y_F)$=0.53, $Corr(I_H,I_F)$=0.36 | | | | | | |
| **(a) Model predictions: Baseline calibration** | | | | | | |
| $Corr(RER, C_H/C_F)$ | -0.07 | -0.39 | -0.79 | -1.00 | -0.10 | 0.03 |
| $Std(RER)$ in % | 2.69 | 2.94 | 4.06 | 1.74 | 1.96 | 7.70 |
| $Std(C_i)$ in % | 0.96 | 0.91 | 2.15 | 0.91 | 0.97 | 1.19 |
| $Std(NX_i/(p_iY_i))$ in % | 0.13 | 0.13 | 0.08 | 0.06 | 0.00 | 0.29 |
| $Corr(C_i, Y_i)$ | 0.63 | 0.65 | 0.99 | 0.57 | 0.48 | 0.83 |
| $Corr(NX_i/(p_iY_i), Y_i)$ | -0.38 | -0.35 | 0.33 | -0.30 | -- | -0.25 |
| $Corr(C_H, C_F)$ | 0.40 | 0.54 | 0.67 | 0.54 | 0.37 | 0.42 |
| **(b) Zero correlation between investment and output** | | | | | | |
| $Corr(RER, C_H/C_F)$ | -0.86 | -0.93 | -0.79 | -1.00 | -0.67 | 0.03 |
| $Std(RER)$ in % | 6.61 | 6.72 | 4.06 | 4.70 | 1.96 | 7.70 |
| $Std(C_i)$ in % | 2.74 | 2.73 | 2.15 | 2.79 | 2.93 | 1.19 |
| $Std(NX_i/(p_iY_i))$ in % | 0.18 | 0.19 | 0.08 | 0.11 | 0.00 | 0.29 |
| $Corr(C_i, Y_i)$ | 0.77 | 0.78 | 0.99 | 0.76 | 0.75 | 0.83 |
| $Corr(NX_i/(p_iY_i), Y_i)$ | 0.14 | 0.15 | 0.33 | 0.20 | -- | -0.25 |
| $Corr(C_H, C_F)$ | 0.70 | 0.72 | 0.67 | 0.64 | 0.49 | 0.42 |
| **(c) High HTM income share,** $\Lambda = 0.6$ | | | | | | |
| $Corr(RER, C_H/C_F)$ | 0.63 | 0.40 | -0.24 | -1.00 | -0.10 | 0.03 |
| $Std(RER)$ in % | 6.04 | 5.78 | 6.01 | 1.74 | 1.96 | 7.70 |
| $Std(C_i)$ in % | 1.11 | 0.98 | 2.17 | 0.91 | 0.97 | 1.19 |
| $Std(NX_i/(p_iY_i))$ in % | 0.24 | 0.23 | 0.16 | 0.06 | 0.00 | 0.29 |
| $Corr(C_i, Y_i)$ | 0.65 | 0.72 | 0.97 | 0.57 | 0.48 | 0.83 |
| $Corr(NX_i/(p_iY_i), Y_i)$ | -0.38 | -0.37 | 0.19 | -0.30 | -- | -0.25 |
| $Corr(C_H, C_F)$ | 0.04 | 0.33 | 0.64 | 0.54 | 0.37 | 0.42 |
| **(d) Low HTM income share,** $\Lambda = 0.25$ | | | | | | |
| $Corr(RER, C_H/C_F)$ | -0.61 | -0.77 | -0.94 | -1.00 | -0.10 | 0.03 |
| $Std(RER)$ in % | 1.92 | 2.20 | 3.66 | 1.74 | 1.96 | 7.70 |
| $Std(C_i)$ in % | 0.93 | 0.91 | 2.15 | 0.91 | 0.97 | 1.19 |
| $Std(NX_i/(p_iY_i))$ in % | 0.09 | 0.10 | 0.06 | 0.06 | 0.00 | 0.29 |
| $Corr(C_i, Y_i)$ | 0.60 | 0.61 | 0.99 | 0.57 | 0.48 | 0.83 |
| $Corr(NX_i/(p_iY_i), Y_i)$ | -0.36 | -0.33 | 0.42 | -0.30 | -- | -0.25 |
| $Corr(C_H, C_F)$ | 0.49 | 0.56 | 0.68 | 0.54 | 0.37 | 0.42 |

**Table 3—ctd.**

| | HTM model Shocks to: | | | Full Risk Sharing Shocks to: | Financial Autarky Shocks to: | |
|---|---|---|---|---|---|---|
| | ***Y,I,λ*** | ***Y,I*** | ***Y,λ*** | ***Y,I*** | ***Y,I*** | **Data** |
| | *(1)* | *(2)* | *(3)* | *(4)* | *(5)* | *(6)* |
| **(e) High risk aversion, $\sigma = 5$** | | | | | | |
| $Corr(RER, C_H/C_F)$ | 0.20 | -0.02 | -0.66 | -1.00 | -0.10 | 0.03 |
| $Std(RER)$ in % | 4.35 | 4.76 | 6.57 | 3.12 | 1.96 | 7.70 |
| $Std(C_i)$ in % | 0.96 | 0.90 | 2.09 | 0.86 | 0.97 | 1.19 |
| $Std(NX_i/(p_iY_i))$ in % | 0.17 | 0.18 | 0.16 | 0.09 | 0.00 | 0.29 |
| $Corr(C_i, Y_i)$ | 0.65 | 0.69 | 0.97 | 0.58 | 0.48 | 0.83 |
| $Corr(NX_i/(p_iY_i), Y_i)$ | -0.33 | -0.29 | 0.39 | -0.11 | -- | -0.25 |
| $Corr(C_H, C_F)$ | 0.39 | 0.60 | 0.79 | 0.73 | 0.37 | 0.42 |
| **(f) High substitution elasticity between domestic and foreign goods, $\phi = 2$** | | | | | | |
| $Corr(RER, C_H/C_F)$ | 0.12 | -0.14 | -0.71 | -1.00 | -0.29 | 0.03 |
| $Std(RER)$ in % | 1.72 | 1.88 | 2.60 | 1.32 | 0.54 | 7.70 |
| $Std(C_i)$ in % | 0.96 | 0.90 | 2.10 | 0.87 | 0.98 | 1.19 |
| $Std(NX_i/(p_iY_i))$ in % | 0.23 | 0.25 | 0.25 | 0.14 | 0.00 | 0.29 |
| $Corr(C_i, Y_i)$ | 0.65 | 0.68 | 0.98 | 0.58 | 0.51 | 0.83 |
| $Corr(NX_i/(p_iY_i), Y_i)$ | -0.30 | -0.26 | 0.40 | -0.01 | -- | -0.25 |
| $Corr(C_H, C_F)$ | 0.40 | 0.59 | 0.75 | 0.71 | 0.35 | 0.42 |
| **(g) High trade share, $\alpha = 0.8$** | | | | | | |
| $Corr(RER, C_H/C_F)$ | -0.41 | -0.59 | -0.54 | -1.00 | 0.55 | 0.03 |
| $Std(RER)$ in % | 0.65 | 0.72 | 1.43 | 0.81 | 1.21 | 7.70 |
| $Std(C_i)$ in % | 0.98 | 0.90 | 2.04 | 0.83 | 1.04 | 1.19 |
| $Std(NX_i/(p_iY_i))$ in % | 0.43 | 0.43 | 0.18 | 0.31 | 0.00 | 0.29 |
| $Corr(C_i, Y_i)$ | 0.66 | 0.70 | 0.93 | 0.63 | 0.25 | 0.83 |
| $Corr(NX_i/(p_iY_i), Y_i)$ | -0.41 | -0.39 | 0.20 | -0.37 | -- | -0.25 |
| $Corr(C_H, C_F)$ | 0.34 | 0.59 | 0.85 | 0.88 | 0.20 | 0.42 |

Note: Cols. (1)-(3) show predictions of the benchmark HTM model. Col. (4): model variant in which all households trade in complete markets; Col. (5): predictions of financial autarky model. Col. (6): average empirical annual statistics for US and G6. Empirical statistics for consumption and the (consumption based) real exchange rate, RER, pertain to non-durables plus services consumption (1971-1987); the sample period for the remaining variables is 1972-2003. Statistics for net exports are based on the first difference of net exports normalized by GDP; the remaining statistics pertain to log growth rates.

**Table 4. The dynamic model: predicted moments (HP filtered)**

| | HTM model Shocks to: | | | Full risk sharing Shocks to: |
|---|---|---|---|---|
| | $\theta,\chi,\lambda$ | $\theta,\chi$ | $\theta,\lambda$ | $\theta,\lambda$ |
| | *(1)* | *(2)* | *(3)* | *(4)* |
| **Baseline calibration** | | | | |
| $Corr(RER, C_H/C_F)$ | -0.30 | -0.81 | -0.08 | -1.00 |
| $Std(RER)$ in % | 1.98 | 1.69 | 0.98 | 1.69 |
| $Std(Y_i)$ in % | 1.10 | 1.10 | 1.08 | 1.11 |
| $Std(I_i)$ in % | 2.55 | 2.24 | 2.49 | 3.04 |
| $Corr(Y_H, Y_F)$ | 0.34 | 0.33 | 0.34 | 0.33 |
| $Corr(C_H, C_F)$ | 0.24 | 0.29 | 0.14 | 0.18 |
| $Corr(I_H, I_F)$ | 0.50 | 0.31 | 0.40 | 0.34 |
| **High risk aversion, $\sigma = 5$** | | | | |
| $Corr(RER, C_H/C_F)$ | -0.03 | -0.75 | 0.01 | -1.00 |
| $Std(RER)$ in % | 2.23 | 1.83 | 1.37 | 2.07 |
| $Std(Y_i)$ in % | 1.09 | 1.08 | 1.08 | 1.09 |
| $Std(I_i)$ in % | 2.56 | 2.21 | 2.58 | 2.93 |
| $Corr(Y_H, Y_F)$ | 0.34 | 0.33 | 0.34 | 0.33 |
| $Corr(C_H, C_F)$ | 0.16 | 0.39 | 0.11 | 0.43 |
| $Corr(I_H, I_F)$ | 0.49 | 0.34 | 0.43 | 0.37 |
| **High substitution elasticity between domestic and foreign goods, $\phi = 2$** | | | | |
| $Corr(RER, C_H/C_F)$ | -0.25 | -0.76 | 0.02 | -1.00 |
| $Std(RER)$ in % | 1.76 | 1.56 | 0.70 | 1.55 |
| $Std(Y_i)$ in % | 1.11 | 1.10 | 1.09 | 1.12 |
| $Std(I_i)$ in % | 2.61 | 2.35 | 2.48 | 3.12 |
| $Corr(Y_H, Y_F)$ | 0.32 | 0.31 | 0.34 | 0.31 |
| $Corr(C_H, C_F)$ | 0.24 | 0.32 | 0.15 | 0.26 |
| $Corr(I_H, I_F)$ | 0.42 | 0.19 | 0.40 | 0.27 |
| **High trade share, $\alpha = 0.8$** | | | | |
| $Corr(RER, C_H/C_F)$ | -0.04 | -0.59 | -0.25 | -1.00 |
| $Std(RER)$ in % | 1.35 | 1.27 | 0.63 | 1.24 |
| $Std(Y_i)$ in % | 1.13 | 1.13 | 1.10 | 1.15 |
| $Std(I_i)$ in % | 3.40 | 3.21 | 2.63 | 3.86 |
| $Corr(Y_H, Y_F)$ | 0.26 | 0.26 | 0.31 | 0.25 |
| $Corr(C_H, C_F)$ | 0.24 | 0.58 | 0.13 | 0.45 |
| $Corr(I_H, I_F)$ | -0.15 | -0.35 | 0.25 | -0.16 |